

# LIQUID CAUSTIC SODA – DILUTION

DOC-1110-0005

Liquid caustic soda 50% freezes at + 12 °C. Diluting this product with softened water could prevent it from freezing : 20% or 25% solutions are the most economic as their respective freezing points are – 25 °C and – 18 °C.

## Principle

The liquid caustic soda 50% inlet pipe is connected to the softened water pipe with a T-piece. The calculated amount of softened water and liquid caustic soda 50% are added simultaneously. The amount of softened water is controlled by a flow meter linked to an automatic shut-off device. A static mixer placed in the pipe after the T-piece minimises temperature gradients in the liquid and produces a homogeneous solution. One-way valves should be inserted in both feed lines.

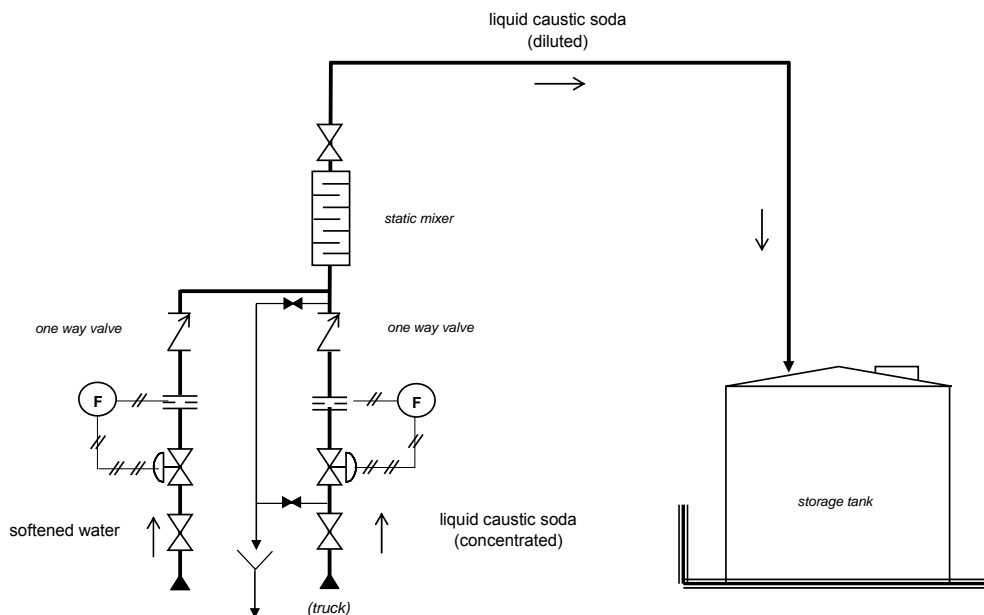
Liquid caustic soda dilution is a strong exothermic process, i.e. product temperature increases instantaneously when water is added: the product could boil and splatter, which could damage the tank.

Liquid caustic soda can be diluted safely by following these precautions:

- choose the appropriate storage tank material (i.e. check the maximum allowed temperature),
- do not dilute in storage tank,
- use softened water with a temperature of approximately 15 °C,
- insert a static mixer after the T-piece,
- adapt the flow rates to the characteristics of the process equipment (i.e. static mixer)

Please consult our safety data sheet.

## Flow Chart

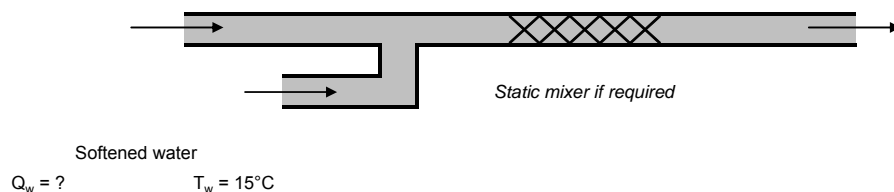


# LIQUID CAUSTIC SODA – DILUTION

## Calculation (example)

Liquid Caustic Soda (Concentrated)  
 $Q_i = 20 \text{ T}$     $C_i = 50\%$     $T_i = 40^\circ\text{C}$

Liquid Caustic Soda (Diluted)  
 $C_f = 25\%$     $T_f = ?$



**What is the required softened water amount -  $Q_w$ ?**

$$Q_w = Q_i \times \frac{(C_i - C_f)}{C_f}$$

With  $Q_i = 20 \text{ tons}$ ,  $C_i = 50\%$ ,  $C_f = 25\%$

$$Q_w = 20 \text{ tons} \times \frac{(50\% - 25\%)}{25\%} = 20 \text{ tons}$$

Note:  $Q = D \times V$ , where  $D$  (\*) is density and  $V$  is liquid caustic soda volume in liters.

(\*) as per *Liquid Caustic Soda – Density table*

$$Q_w = 20 \text{ tons}$$

**What is the final temperature -  $T_f$ ?**

Reagents enthalpy:

$$20 \text{ ton NaOH } 50\% \text{ at } 40^\circ\text{C} \text{ (**)} \quad +343,9 \text{ kJ kg}^{-1} \times 20000 \text{ kg} = \quad + 6878 \text{ MJ}$$

$$20 \text{ ton Water at } 15^\circ\text{C} \text{ (**)} \quad +63,2 \text{ kJ kg}^{-1} \times 20000 \text{ kg} = \quad + 1264 \text{ MJ}$$

$$\text{Total} \quad \quad \quad + 8142 \text{ MJ}$$

Final solution enthalpy:

$$40 \text{ ton NaOH } 25\% \text{ at } 40^\circ\text{C} \text{ (**)} \quad -145,5 \text{ kJ kg}^{-1} \times 40000 \text{ kg} = \quad - 5820 \text{ MJ}$$

$$\text{Liberated heat:} \quad 8142 \text{ MJ} - 5820 \text{ MJ} = \quad + 2322 \text{ MJ}$$

$$\text{Temperature increase (***)}: \quad 2322 \text{ MJ} / (3,625 \text{ kJ kg}^{-1} \text{ }^\circ\text{C}^{-1} \times 40000 \text{ kg}) = \quad + 16^\circ\text{C}$$

$$\text{Final temperature:} \quad 40^\circ\text{C} + 16^\circ\text{C} = \quad + 56^\circ\text{C}$$

(\*\*) As per *Liquid Caustic Soda – Enthalpy table*

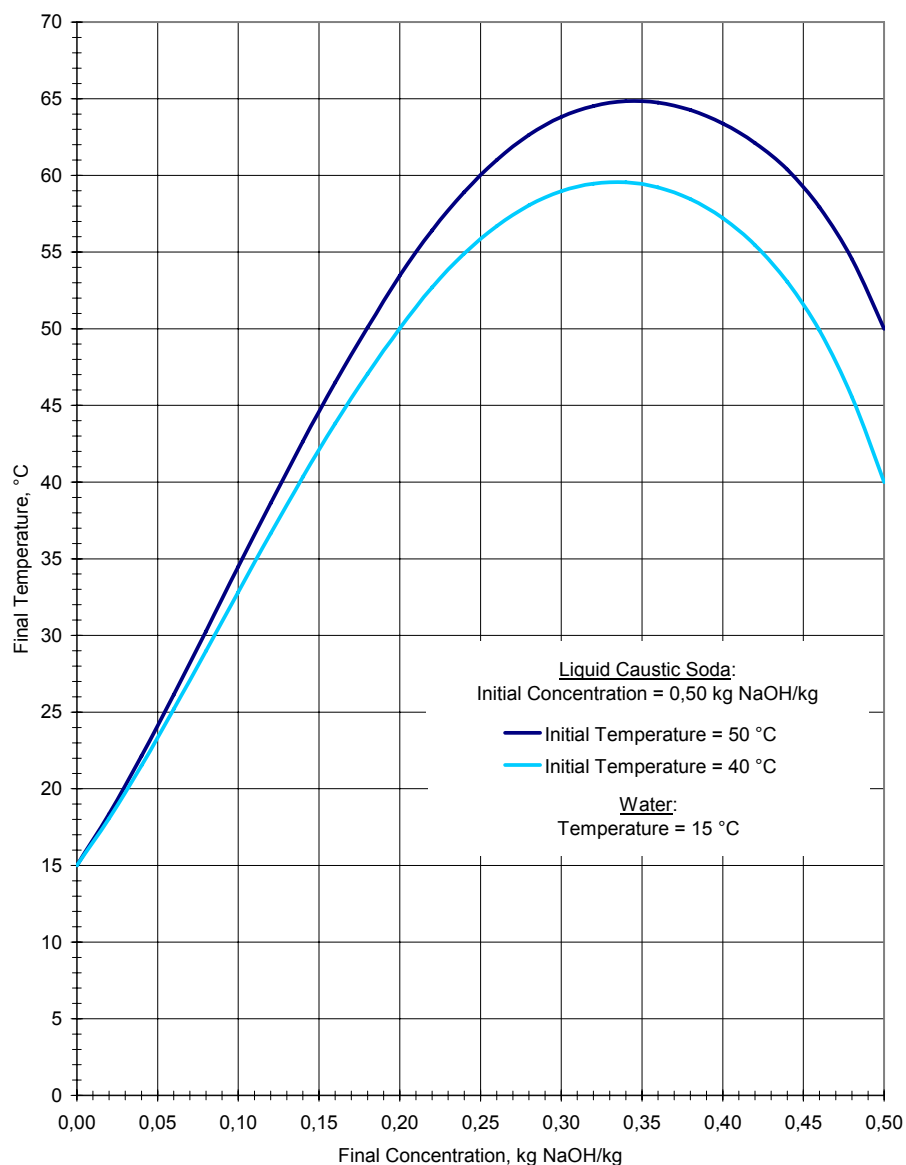
(\*\*\*) As per *Liquid Caustic Soda – Specific Heat table*

$$T_f \sim 56^\circ\text{C}$$

20 tons water are required to dilute 20 tons liquid caustic soda from 50% to 25% and  $56^\circ\text{C}$  would be the approximate final liquid temperature.

# LIQUID CAUSTIC SODA – DILUTION

Liquid Caustic Soda - Dilution with Water  
Final Temperature



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## LIQUID CAUSTIC SODA - ENTHALPY

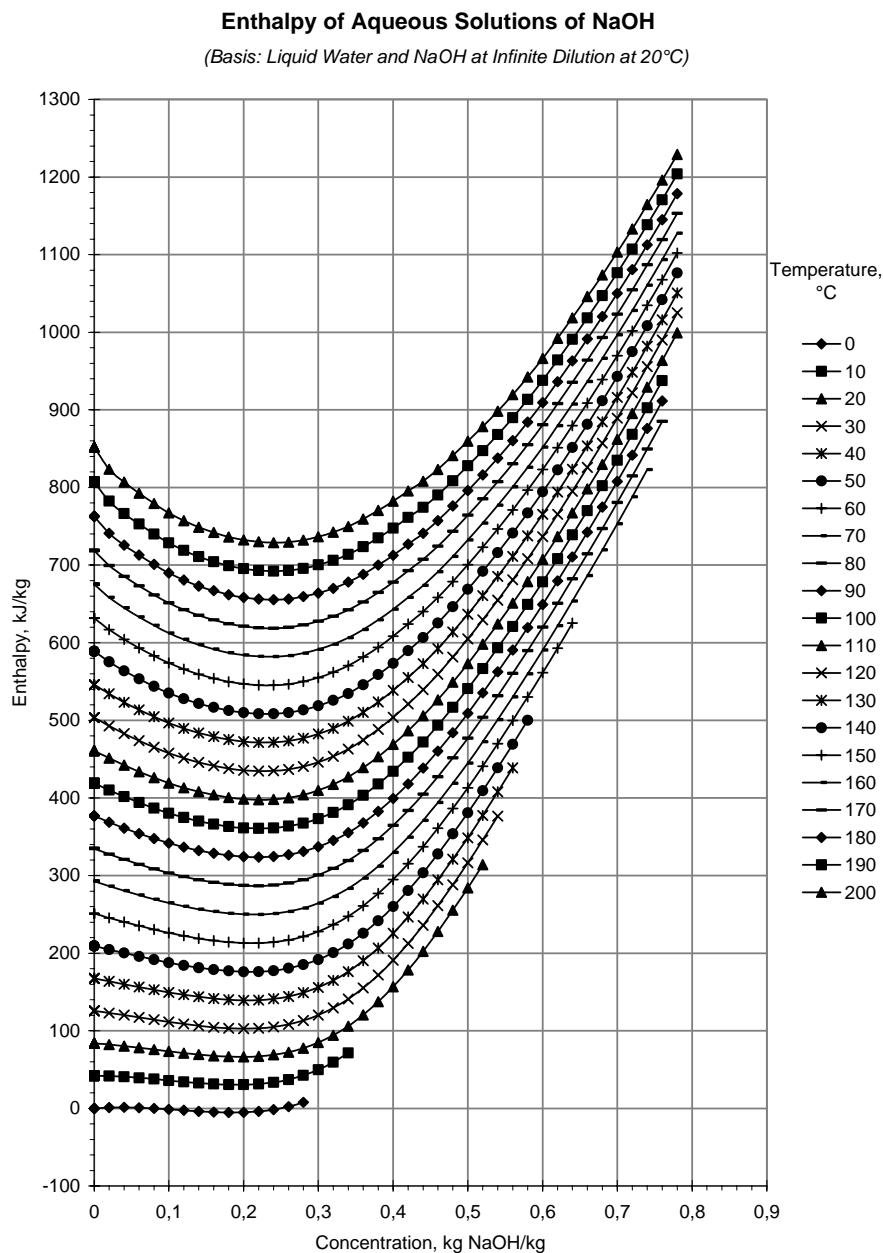
PCH-1110-0002

Concentration, kg NaOH/kg		Enthalpy of Aqueous Solutions of NaOH, kJ/kg (Basis : Liquid Water and NaOH at Infinite Dilution at 20°C)																			
		Temperature, °C																			
0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	
0.00	0.0	41.8	84.6	128.8	168.9	211.1	254.6	299.5	341.5	383.0	424.6	466.8	508.7	550.6	592.7	635.0	677.5	720.1	763.1	806.4	849.9
0.02	1.2	41.9	82.3	123.0	163.8	204.6	245.6	287.3	328.4	369.5	410.6	452.0	493.4	534.8	576.4	618.1	660.0	702.1	744.4	786.9	829.7
0.04	1.4	41.1	79.7	119.2	158.8	198.5	237.5	276.5	316.9	357.5	398.2	439.0	479.8	520.8	561.9	603.0	644.4	685.8	727.5	769.3	811.4
0.06	1.0	39.7	76.9	115.5	154.1	192.9	230.4	267.3	307.0	347.2	387.5	427.6	468.0	508.5	549.0	589.7	630.5	671.4	712.4	753.6	795.0
0.08	0.0	37.9	74.2	111.9	149.9	187.9	224.3	259.6	298.7	338.5	378.3	417.8	457.8	497.8	538.6	578.1	618.4	658.7	699.2	739.8	780.5
0.10	-1.3	36.0	71.6	108.8	146.1	183.6	219.2	253.4	292.0	331.4	370.8	409.7	449.3	488.9	528.6	568.3	608.0	647.8	687.8	727.8	767.9
0.12	-2.7	34.0	69.3	106.1	143.0	180.1	215.2	248.7	286.8	325.8	364.8	403.3	442.5	481.6	520.8	560.1	599.4	638.7	678.1	717.6	757.1
0.14	-3.9	32.2	67.5	104.0	140.6	177.4	212.3	245.5	283.2	321.8	360.4	398.5	437.2	476.0	514.8	553.6	592.4	631.3	670.2	709.1	748.1
0.16	-4.9	30.8	66.3	102.6	139.1	175.7	210.7	243.8	281.1	319.4	357.6	395.3	433.6	472.0	510.3	548.7	587.1	625.5	663.9	702.4	740.8
0.18	-5.3	30.1	65.9	102.1	138.5	175.0	210.2	243.5	280.6	318.5	356.4	393.7	431.6	469.6	507.5	545.5	583.5	621.4	659.4	697.3	735.3
0.20	-5.1	30.2	66.4	102.5	138.9	175.4	211.0	244.8	281.6	319.1	356.6	393.6	431.2	468.8	506.3	543.9	581.4	619.0	656.5	694.0	731.5
0.22	-3.9	31.3	67.9	104.1	140.5	177.0	213.1	247.5	284.1	321.3	358.5	395.2	432.4	469.6	506.7	543.9	581.0	618.2	655.3	692.3	729.4
0.24	-1.5	33.6	70.7	106.9	143.3	179.9	216.6	251.7	288.1	325.0	361.8	398.2	435.1	471.9	508.7	545.4	582.2	618.9	655.6	692.3	728.9
0.26	2.2	37.4	74.8	111.1	147.6	184.2	221.5	257.5	293.7	330.2	366.6	402.9	439.3	475.7	512.2	548.6	584.9	621.3	657.6	693.8	730.0
0.28	7.4	42.8	80.5	116.7	153.3	190.0	227.8	264.7	300.7	336.9	373.0	409.0	445.1	481.1	517.2	553.2	589.2	625.2	661.1	696.9	732.8
0.30	0.40	50.0	87.8	124.0	160.6	197.3	235.6	273.3	309.2	345.1	380.8	416.6	452.3	488.0	523.7	559.4	595.0	630.6	666.1	701.6	737.0
0.32	0.32	59.3	96.9	133.0	169.5	206.2	244.9	283.5	319.3	354.7	390.2	425.7	461.1	496.4	531.7	567.0	602.3	637.5	672.7	707.8	742.8
0.34	0.34	70.8	107.9	143.9	180.3	216.9	255.8	295.2	330.7	365.9	401.0	436.3	471.3	506.3	541.2	576.1	611.0	645.9	680.7	715.4	750.2
0.36	0.36	121.1	156.9	193.0	229.4	268.4	308.3	343.7	378.5	413.2	448.3	482.9	517.6	552.1	586.7	621.2	655.7	690.2	724.6	758.9	
0.38	0.38	136.6	171.9	207.7	243.7	282.6	322.9	358.1	392.5	426.9	461.8	496.0	530.3	564.5	598.7	632.9	667.0	701.1	735.1	769.1	
0.40	0.40	154.4	189.2	224.4	260.1	296.5	333.0	369.0	404.1	442.1	476.6	510.5	544.4	578.3	612.1	645.9	679.7	713.4	747.1	780.7	
0.42	0.42	174.8	208.9	243.5	278.5	316.1	356.5	391.3	425.0	458.7	492.9	526.5	560.0	593.5	626.9	660.3	693.7	727.1	760.4	793.7	
0.44	0.44	197.9	231.1	264.8	299.0	335.6	375.6	410.0	443.4	476.6	510.6	543.8	576.9	610.0	643.1	676.1	709.2	742.2	775.1	808.0	
0.46	0.46	223.9	256.0	288.6	321.8	356.9	396.1	430.2	463.1	496.0	529.7	562.4	595.2	627.9	660.6	693.3	725.9	758.5	791.1	823.7	
0.48	0.48	252.9	283.6	314.9	346.9	380.0	418.0	451.8	484.3	516.8	550.1	582.5	614.8	647.1	679.5	711.7	744.0	776.2	808.4	840.6	
0.50	0.50	285.1	314.1	343.9	374.5	405.1	441.5	474.8	506.9	539.0	571.9	603.8	635.8	667.7	699.6	731.5	763.4	795.2	827.0	858.8	
0.52	0.52	320.5	347.7	375.6	404.5	432.2	466.4	499.1	530.9	562.6	594.9	626.5	658.6	689.6	721.1	752.5	784.0	815.4	846.8	878.2	
0.54	0.54		384.4	410.2	437.1	461.3	492.8	524.9	556.2	587.5	619.4	650.5	681.6	712.7	743.8	774.8	805.8	836.9	867.9	898.8	
0.56	0.56			447.8	472.4	492.5	520.6	552.1	583.0	613.8	645.1	675.8	706.4	737.1	767.7	798.3	828.9	859.5	890.1	920.6	
0.58	0.58				510.4	525.7	549.9	580.6	611.0	641.4	672.0	702.3	732.5	762.7	792.9	823.1	853.2	883.3	913.4	943.5	
0.60	0.60					561.1	580.7	610.5	640.5	670.4	700.3	730.1	759.8	789.6	819.3	849.0	878.6	908.3	937.9	967.5	
0.62	0.62					598.7	613.0	641.8	671.3	700.6	729.8	759.1	788.4	817.6	846.9	876.1	905.2	934.4	963.5	992.6	
0.64	0.64					638.5	646.7	674.4	703.4	732.2	760.5	789.4	818.1	846.9	875.6	904.3	933.0	961.6	990.2	1018.8	
0.66	0.66						681.8	708.4	736.8	765.1	792.5	820.8	849.1	877.3	905.5	933.7	961.8	989.9	1017.9	1045.9	
0.68	0.68						718.4	743.7	771.5	799.3	825.6	853.4	881.2	908.9	936.5	964.1	991.7	1019.2	1046.6	1074.0	
0.70	0.70						756.5	780.3	807.6	834.8	860.0	887.2	914.4	941.6	968.8	995.7	1022.6	1049.5	1076.4	1103.1	
0.72	0.72						796.0	818.2	844.9	871.5	895.5	922.2	948.8	975.4	1001.8	1028.3	1054.6	1080.9	1107.0	1133.1	
0.74	0.74						837.0	857.5	883.5	909.5	932.2	958.3	984.3	1010.3	1036.1	1061.9	1087.6	1113.2	1138.7	1164.1	
0.76	0.76							898.0	923.4	948.7	970.0	995.5	1020.9	1046.2	1071.4	1096.5	1121.5	1146.4	1171.2	1195.8	
0.78	0.78										1009.0	1033.8	1058.6	1083.2	1107.8	1132.2	1156.5	1180.6	1204.6	1228.4	

References : McCabe, Trans. A.I.Ch.E. 31, 129 (1935) - Bertetti et McCabe, Ind. Eng. Chem. 28, 247 (1936) - Bertetti et McCabe, Ind. Eng. Chem. 28, 375 (1936) - McCabe et Wilson, Ind. Eng. Chem. 34, 558 (1942)

# LIQUID CAUSTIC SODA - ENTHALPY

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## LIQUID CAUSTIC SODA - SPECIFIC HEAT

PCH-1110-0004

Specific Heat of Aqueous Solutions of NaOH, kJ.kg <sup>-1</sup> .°C <sup>-1</sup>																					
Temperature, °C		Concentration, kg NaOH/kg																			
		0,00	0,02	0,04	0,06	0,08	0,10	0,12	0,14	0,16	0,18	0,20	0,22	0,24	0,26	0,28	0,30	0,32	0,34	0,36	0,38
	0	4,204	4,041	3,921	3,831	3,757	3,695	3,647	3,610	3,575	3,550	3,527	3,508	3,534	3,517	3,499	3,482	3,465	3,444	3,428	3,416
	10	4,190	4,053	3,947	3,867	3,796	3,738	3,692	3,656	3,624	3,598	3,574	3,554	3,572	3,556	3,539	3,522	3,504	3,484	3,465	3,446
	20	4,181	4,063	3,969	3,894	3,827	3,772	3,728	3,692	3,663	3,637	3,613	3,593	3,605	3,589	3,573	3,556	3,538	3,517	3,496	3,471
	30	4,177	4,072	3,985	3,915	3,851	3,798	3,756	3,721	3,693	3,667	3,645	3,624	3,605	3,589	3,573	3,556	3,538	3,517	3,496	3,471
	40	4,176	4,080	3,999	3,931	3,869	3,819	3,778	3,743	3,716	3,690	3,669	3,649	3,632	3,617	3,602	3,585	3,566	3,545	3,520	3,491
	50	4,177	4,088	4,010	3,943	3,883	3,834	3,794	3,759	3,732	3,707	3,687	3,669	3,654	3,639	3,624	3,608	3,588	3,566	3,539	3,507
	60	4,182	4,096	4,019	3,951	3,893	3,845	3,805	3,770	3,743	3,718	3,699	3,682	3,666	3,651	3,635	3,615	3,590	3,560	3,525	
	70	4,187	4,104	4,027	3,959	3,901	3,852	3,813	3,777	3,750	3,725	3,708	3,691	3,676	3,661	3,645	3,620	3,594	3,564	3,528	
	80	4,194	4,113	4,035	3,966	3,909	3,858	3,818	3,782	3,754	3,729	3,712	3,696	3,685	3,670	3,656	3,640	3,620	3,594	3,564	3,528
	90	4,201	4,124	4,043	3,975	3,916	3,863	3,822	3,784	3,756	3,731	3,713	3,696	3,685	3,670	3,656	3,640	3,620	3,594	3,564	3,529
	100	4,207	4,137	4,053	3,986	3,926	3,868	3,825	3,786	3,758	3,732	3,714	3,697	3,685	3,670	3,656	3,640	3,620	3,594	3,564	3,529
	110																				
	120																				
	130																				
	140																				
	150																				
Temperature, °C		Concentration, kg NaOH/kg																			
		0,40	0,42	0,44	0,46	0,48	0,50	0,52	0,54	0,56	0,58	0,60	0,62	0,64	0,66	0,68	0,70	0,72	0,74	0,76	0,78
	0	3,398	3,378	3,362	3,322	3,280	3,231														
	10	3,424	3,395	3,369	3,326	3,277	3,225	3,181	3,120	3,065	3,016	2,955	2,913	2,863	2,825	2,777	2,734	2,701	2,661		
	20	3,445	3,409	3,369	3,326	3,274	3,220	3,169	3,104	3,046	3,001	2,950	2,905	2,857	2,818	2,771	2,727	2,684	2,652	2,626	2,599
	30	3,460	3,419	3,375	3,326	3,270	3,215	3,164	3,098	3,039	2,994	2,943	2,890	2,851	2,811	2,771	2,734	2,701	2,678	2,645	2,620
	40	3,472	3,426	3,379	3,326	3,266	3,210	3,158	3,092	3,033	2,986	2,936	2,883	2,837	2,791	2,751	2,713	2,678	2,645	2,620	2,590
	50	3,479	3,431	3,380	3,324	3,261	3,206	3,153	3,088	3,028	2,978	2,929	2,876	2,830	2,784	2,745	2,707	2,671	2,638	2,613	2,583
	60	3,483	3,433	3,379	3,320	3,256	3,202	3,148	3,084	3,024	2,971	2,921	2,870	2,823	2,777	2,738	2,700	2,664	2,632	2,605	2,578
	70	3,485	3,434	3,375	3,314	3,250	3,196	3,144	3,084	3,024	2,971	2,921	2,870	2,829	2,791	2,751	2,713	2,678	2,645	2,620	2,590
	80	3,485	3,434	3,375	3,314	3,250	3,196	3,144	3,084	3,024	2,971	2,921	2,870	2,829	2,791	2,751	2,713	2,678	2,645	2,620	2,590
	90	3,484	3,433	3,369	3,306	3,250	3,196	3,144	3,084	3,024	2,971	2,921	2,870	2,829	2,791	2,751	2,713	2,678	2,645	2,620	2,590
	100	3,484	3,433	3,360	3,297	3,245	3,193	3,139	3,079	3,019	2,963	2,913	2,860	2,822	2,784	2,745	2,707	2,671	2,638	2,613	2,583
	110						3,193	3,135	3,074	3,014	2,956	2,906	2,864	2,822	2,784	2,745	2,707	2,671	2,638	2,613	2,583
	120						3,191	3,131	3,068	3,008	2,949	2,898	2,857	2,815	2,777	2,738	2,700	2,664	2,632	2,605	2,578
	130						3,189	3,126	3,062	3,001	2,942	2,891	2,850	2,808	2,770	2,731	2,694	2,658	2,626	2,597	2,572
	140						3,187	3,122	3,054	2,993	2,936	2,886	2,842	2,802	2,762	2,724	2,687	2,652	2,619	2,590	2,565
	150						3,185	3,118	3,045	2,983	2,931	2,881	2,833	2,797	2,753	2,717	2,679	2,646	2,612	2,583	2,557

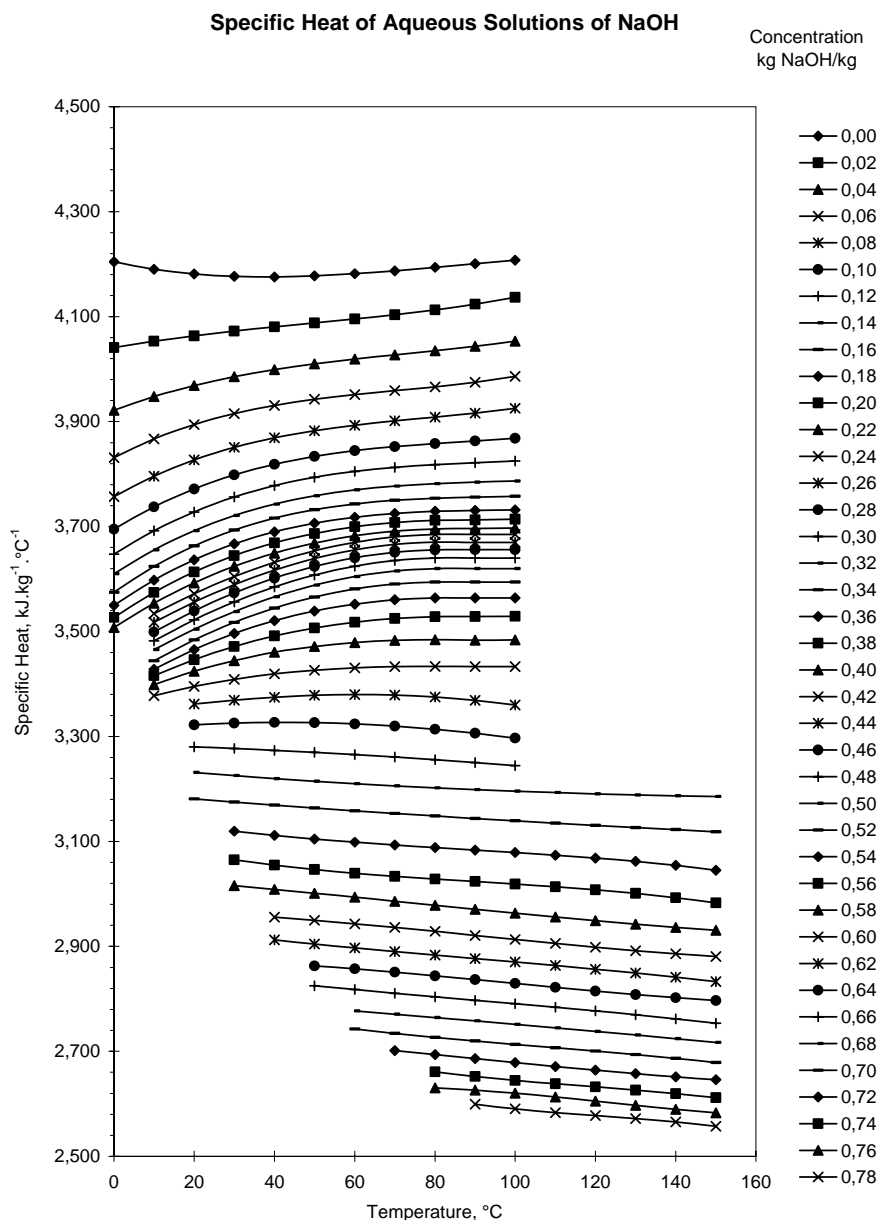
References : Benfell & McCabe, Ind. and Engineering Chemistry, 28, 375 (1936) - McCabe & Wilson, Ind. and Engineering Chemistry, 34, 558 (1942)

References : Bertell &amp; McCabe, Ind. and Engineering Chemistry, 28, 375 (1936) - McCabe &amp; Wilson, Ind. and Engineering Chemistry, 34, 558 (1942)

## LIQUID CAUSTIC SODA - SPECIFIC HEAT

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